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Residential energy consumption trends, main drivers and policies in Lithuania

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ABSTRACT

Environmental pressure from residential energy use is projected to significantly increase by 2030. Different environmental policy measures provide different incentives for “environmentally responsive” consumer choices and behavioural responses. There is a great energy saving potential in residential buildings of Lithuania. Compared to the other EU countries with similar climate conditions, energy consumption for residential heating is approximately 1.8 times higher in Lithuania. About 60% of Lithuanian population resides in multi-apartment buildings constructed during 1961–1990. The aim of the paper is to define the main drivers of residential energy use in Lithuania and to compare energy saving technologies in terms of energy saving potential and costs in Lithuanian residential buildings. Seeking to achieve the aim the main tasks of the paper are to analyse theoretical issues of the main drivers of residential energy use; to analyse residential energy use trends in Lithuania and to compare these trends with other EU member states; to define the main drivers of residential energy use by applying correlation analysis; to analyse policies aiming to reduce energy consumption in residential buildings and their impacts on GHG emission reduction.

The comparative study of residential energy use in Lithuania and several old EU member states showed that residential energy use per capita in Lithuania is significantly lower than in old EU member states because of the lower income per capita and lower living standards. The economic and technological factors are the main driving forces of final energy consumption in all compared EU member states; however the impact of different factors varies between countries. The comparative analysis of energy saving and GHG emission reduction potential and costs in residential buildings provided by different studies showed that the most cost-effective instruments were appliance standards, energy efficiency obligations, Demand Side Management programs, public benefit charges and labelling.

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1. Introduction

There is obvious increasing environmental pressure from residential energy use and it is expected to increase even further. One of the key determinants of residential energy use patterns is economic growth and especially growth of living standards in developing countries. Therefore many countries have implemented policies aiming at energy efficiency improvements. These policies which provide economic incentives to save energy play crucial role in driving energy consumption patterns in household. However, household responsiveness to economic incentives may be limited because of the existence of non-economic motivations. For example, the apparent gap between long-run and short-run preferences of agents, reflecting extremely high discount rates. This is of particular relevance for policies targeting residential energy use, where agents fail to adopt energy-efficient technologies that are cost-effective. Based on paradigm of behavioural economics [1] the society can shape individual preferences and beliefs, in particular through institutions and social norms, and socialization processes. Different models can be applied to explain environmental behaviour – such as the theory of planned behaviour and the value-norm-belief model [2,3]. These models prove to be relevant for analysis of residential energy use. Better understanding of how norms and values can affect the environmental behaviour of individuals can provide useful insights to policy makers for choosing (and combining) instruments to improve the effectiveness and efficiency of policies [4]. Government can also influence norms, in particular, through information-based instruments such as communication campaigns; this may also contribute to increasing the acceptability of policies.

As energy consumption is growing in many EU member states, though a lot of policies aiming at energy conservation in residential sector were implemented, therefore it is important to analyse residential energy consumption trends and the main drivers of energy consumption between countries seeking to define the major issues of concern and to develop policies targeting these issues.

The technical potentials for energy efficiency are enormous in all sectors – cars could reduce energy consumption by half without any change in comfort levels. Buildings, through the integration of renewables, could even become small "power houses" that produce net more energy than they consume [5]. Much more important is, however, a realistic estimate at which costs these potentials can be realised beyond those potentials that are realised in an autonomous way anyhow. The current high energy prices can strongly enhance the uptake of energy efficient technologies and procedures.

The majority of residential buildings representing housing sector in Lithuania is physically worn and their condition does not satisfy the resident's needs. The tendency of decrease of energy consumption in housing is reflected in the new technical regulations on construction in Lithuania; however the situation still needs improvement. Until now the COWI study [6,7] was the first attempt to evaluate CO_2 emission reduction costs in the entire Lithuanian building stock. The COWI study addressed the emission reduction options and costs across all sectors of the Lithuanian economy. The purpose of this study was to give the approximation of costs in Lithuanian economy in the case of the carbon emission target tightening. CO_2 reduction costs were evaluated from the side of the state budget as the support in the form of investment subsidizing. There are many studies conducted in other countries assessing energy saving costs and potentials including GHG emission reduction costs and potentials [8–16].

The aim of the paper is to define the main drivers of household energy consumption. Seeking to achieve the aim the following tasks were defined:

- To analyse theoretical findings for the main drivers of residential energy use;
- To analyse residential energy use trends in Lithuania and to compare these trends with other EU member states;
- To define the main drivers of residential energy use;
- To analyse policies aiming to reduce energy consumption in residential buildings and their impacts on energy savings and GHG emission reduction;
- To analyse energy saving policies and energy saving potential and costs in Lithuanian residential buildings;
- To develop policy recommendations for residential energy saving policy in Lithuania.

The methods applied include regression analysis, comparative analysis of studies conducted in Lithuania and assessment of GHG emission reduction potential in residential buildings based on energy saving potential and national GHG emission factors.

2. Theoretical background of residential energy use drivers

In standard economic models, individual decision-making is based on the assumptions of rational behaviour according to which individuals make choices that maximize their well-being. These assumptions are often supported by empirical evidence: people facing policy incentives will respond generally in a manner consistent with welfare maximization. Pricing will induce a change in consumption decisions, standards will also affect decision-making. Because of the existence of search costs, the provision of information to individuals will also allow them to express their demand for environmental quality. The approach here seeks for the examination of other possible criteria, including cultural, psychological, institutional and other issues. As countries differ in terms of cultural values, psychological characteristics, etc. it is important to explore these issues in analysing drivers of residential energy use. Therefore, this paper is based on the idea that energy demand is essentially driven by economic and non-economic factors. Non-economic factors can be divided into technological, policy and others. Others include cultural, psychological and institutional factors. The main economic factors driving residential energy use are income and prices. Though economic factors are very important there are a number of market failures that challenge the economic analysis of energy demand, such as informational failures, imperfect capital markets, etc.

2.1. Economic factors

Income is a key driver of residential energy demand. As households become richer, they can afford to use combinations of energy and capital goods as substitutes for input of time. Furthermore, as income increases, households might make intra-fuel substitutions and switch from one heating system to another that is likely to be more efficient. In addition income encompass also many of the attitudinal variables that affect demand. If the relative price of energy increases, the reductions of demand are expected. It is also known from basic economic theory that there is a close link between price elasticity and substitution possibilities. Hence, when substitution possibilities are limited, price elasticities are small. A household facing higher energy prices can apply different options to lessen the impact of the price increase on their budget. Because these substitution possibilities vary across households the price elasticities vary across the population. Therefore demand for energy is generally quite price-inelastic. The short-run price elasticity is 0.3 and the long-run price elasticity is 0.7. The important point is that energy demand responds to price just over the long run. Energy demand responds also to income. More recent estimates tend to suggest rather low income elasticities

especially in short term [17–20]. Therefore demand for energy is generally quite price-inelastic.

2.2. Non-economic factors

Non-economic factors can be divided into technological, policy and others. Others include cultural, psychological and institutional factors. The technological factors are usually being considered among the main drivers of residential energy use as advances in new technologies allow implementing modern energy systems, appliances, insulation equipment, etc. in residential buildings having direct impact on energy conservation in residential sector. The technological factors are usually being considered among the main drivers of residential energy use as advances in new technologies allow to implement modern energy systems, appliances, insulation equipment, etc. in residential buildings having direct impact on energy conservation in residential sector. While there is a plethora of studies on the technical possibilities, i.e. the potential energy savings that new technologies allow, it is obvious that energy consumption also depends on attitudes, preferences and income as well as relative prices. As technology improves, households can enjoy the same stream of services but with a lower energy input. The literature on the so-called "rebound effect" holds that efficiency improvements can paradoxically lead to higher energy use [21,22]. For example, if someone invests in more efficient air-conditioning, he keeps his energy bill constant by adjusting the thermostat on the new device. As decisions to buy a capital good are affected by income, the ultimate reason why energy use changes may well be changes in prosperity.

Attitudinal variables portray an individual's state of mind or feeling. A definition of "attitude" in social psychology is the valuation of a concept or an object [23]. Studies [23–25] summarize the literature related to environmental concerns, arguing that these concerns are only weakly correlated with socio-demographic and psychological factors. Therefore other factors – cultural, psychological, institutional have direct impact on household preferences and attitudes. It is obvious that demand for energy depends on the household's preferences for goods and services. Preferences vary across populations; the elderly may well prefer an in-door temperature that does not suit the young and, as many parents of teenagers will testify, the number of showers varies with a household's demographic composition. Empirical research on residential energy demand shows how demand fluctuates between households of different sizes, composition and so on. Besides that demand differs between households of a given social class living in the same category of buildings. Importantly, even households with the same kind of equipment consume energy at different levels. EU barometer provides some information about attitudinal variables, such as the households' view towards "green" consumption across the EU which are varying across EU countries. Different preferences can help inexplanation of this fact. Because preferences differ, it is obvious that two households with identical observable characteristics (income, education, sex and so on) may demand different baskets of goods, including energy goods. Detailed research [24] shows that similar households living in similar housing display widely varying energy consumption patterns. The conclusion is that if preferences are heterogeneous across the population, the response to price changes may well differ between otherwise identical households. The preferences and attitudes are related with individual characteristics of households as well with cultural values and psychological characteristics. Institutional issues also play an important role to represent the institutional capital having positive impact on behaviour patterns and attitudes of the people. Policies aiming at overcoming market failures have impact on residential energy use as well.

2.3. Policies

Generally the policies are being developed and implemented because of market failures. One of the most widely known market failures in the environmental energy policies are externalities. However there are other market failures having impact on residential energy use. Policy makers may need to use policies and measures to remove other failures in addition to the instruments more directly targeting the environmental externality, such as energy tax. These other sources of market barriers and failures include information asymmetries, failures on the capital market and split incentives such as landlord/tenant problem. Some of these measures need to be targeted at specific household groups to improve the effectiveness and efficiency of the policy. Considering differences in environmental behaviour among household groups may facilitate this process. The provision of information to consumers allows them to make informed choices. The slow adoption of environmentally preferable goods is mainly due to information failures and high search costs. Information-based instruments, such as energy labels for appliances and building certificates are being introduced in combination with energy taxes by the Government. In addition there are differences in access to information across households which prevent some household groups from expressing their underlying demand for environmental quality. Low-income households face constraints to access the credit market, preventing them from making investments in environmentally preferable goods (buying alternative fuel vehicles, energy efficient equipment, etc.) which would be cost effective for them to undertake [26]. Therefore policy makers need to adopt policies and measures to address these market failures and barriers. These measures include preferential loans targeting vulnerable households. Some households may face few incentives to invest in environmentally preferable goods or to adopt environmental behaviour. For instance, the landlord has little incentive to choose the most energy-efficient equipment like space heaters or lighting systems and to invest in isolation, when the tenant benefits from these choices through reduced energy bills to be paid. Therefore Government needs to introduce targeted policies and measures to address these all market failures having direct impact on residential energy use.

3. Residential energy use trends in Lithuania and EU

The term "residential energy use" typically includes space heating, water heating and household electricity consumption. Heating/cooling is a major part of demand. Though income has grown by more than 2% per year in the OECD area since 1970 simultaneously, efficiency improvements have been secured throughout the period. Income has a positive effect on demand, while price increases tend to slow it down. The net impact of these factors is uncertain, because efficiency improvements might well be dwarfed by an increasing demand.

As climate fluctuates from 1 year to another the data is being presented usually as climate corrected. Between 1990 and 2008, the final household energy consumption increased by 13% in the EU-27, at an annual average growth rate of 0.7%. Over the same period, final household electricity consumption increased faster, at an annual growth rate of 1.9%. From 1990 to 2008 per capita household energy consumption increased by 0.4%/year in the EU-27 countries. Between 1990 and 2008, the electricity consumption per capita in the household sector in the EU-27 increased by 32%, at an annual average rate of 1.6% per year. All member states show a rise in per capita consumption except Sweden (−5%). However during the same period household energy consumption per dwelling (climate corrected) decreased by 6.4% in the EU-27 (0.4%/year)

particularly due to efficiency improvements and rising energy prices. With the increase of the average income per household, the average size of dwellings is increasing, but the energy consumption per dwelling is decreasing. This results in energy efficiency progress (−1.2%/year), due to better thermal performance of buildings but offset by more appliances and larger homes. Indeed the increasing size of dwellings and more electrical appliances contributed to increase the average consumption per dwelling by 0.4% a year each (rebound effect).

Heating demand, even corrected for differences in climate and fuel mix, varies significantly among EU-27 countries. Apart from Bulgaria and Spain which have the lowest rate of penetration of central heating (around 40% and 60% respectively), almost all countries have more than 70% of central heating and can be compared; among them the gap in useful consumption per m^2 is important (a factor 2). Nordic countries, such as Norway or Finland, the Netherlands and even Slovakia are among the best performers, i.e. the countries with the lowest heating consumption per m^2. Over the period 1997–2008, the highest efficiency improvement is performed by new member states Poland, Romania, Lithuania and Estonia, with an annual average rate of energy efficiency improvement above 2%. This can be explained by the high energy efficiency potentials available in these countries due to outdated infrastructures (e.g. buildings, heating supply systems, etc.).

Space heating is the largest component of energy use in virtually all member states, accounting for around 70% of the total residential energy use. The recent penetration of central heating (in the southern European countries and in Ireland) has also contributed to increase the energy consumption in the household sector. The share of the electricity consumption for lighting and appliances in the total household consumption has increased by 4 points, from 10% to 14% since 1990, which tends to affect the rise in the overall energy consumption per dwelling. As a result of all these different changes in lifestyles (i.e. increase in the size of dwellings and in the number of large appliances and central heating), around 70% of the energy efficiency progress achieved through technological development has been offset by increasing energy consumption in EU.

The residential energy use and the main drivers of final energy consumption were further analysed in Lithuania, the Netherlands, the United Kingdom and Germany. The main economic drivers of final energy consumption in household selected in the study are energy prices and real disposable income. The main technological drivers of residential energy useare the patents for high technologies per mill. of inhabitants, the share of population working in science and high technologies sector. The other drivers of residential energy useare institutional indicators. The analysis of energy consumption trends in few EU member states were conducted by applying macroeconomic or top-down approach then the impact macroeconomic indicators on final energy consumption trends were investigated by applying correlation and regression analysis. The four states specific with rather similar geo-political situation were chosen for the analysis, namely Lithuania, the United Kingdom, the Netherlands, and Germany. The data from EUROSTAT, however, exhibited some divergence between these countries. For instance, the overall energy consumption decreased in Germany and Lithuania during 1990–2009 by some 7% and 54%, respectively. Indeed, the same figure for Lithuania falls to 11% if considering the period of 1993–2009. Meanwhile, the Netherlands and the United Kingdom experienced growth in the final energy consumption of 21% and 1%, respectively. The fall in energy consumption observed in Lithuania might be attributed to the complex post-communist transformations undergone there during the last decade of the 20th century. The household sector maintains an inelastic energy demand and thus non-decreasing share in energy consumption structure. As for the four states analysed in this paper the household energy consumption accounted for some 30% of the final energy consumption with exception of the Netherlands where it shrunk down to 20%.

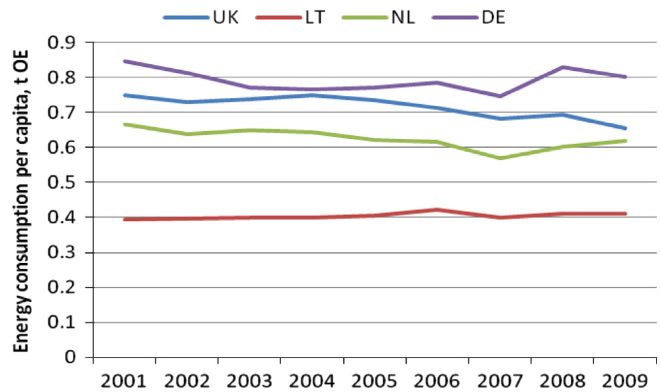

Fig. 1. Residential energy use per capita of the selected states, 2001–2009.

Indeed, the level of energy consumption in the household sector per capita is rather different across the analysed countries (Fig. 1). As one can note, Lithuanian households consume less energy per capita compared to those in the United Kingdom, the Netherlands, or Germany. However, it trends upward, albeit it is unlikely to approach level of the remaining states. Germany is specific with the highest household energy consumption, namely some 0.8 t of oil equivalent (toe) in 2009. These differences can be explained by different living standards in Lithuania and the remaining states where the rebound effect comes into effect.

The correlation analysis was employed to research into the technological, social, economic, and institutional factors influencing residential energy use and associated GHG emission across the United Kingdom, Lithuania, the Netherlands, and Germany. The data come from EUROSTAT and Kaufmann et al. [27]. The technological indicators cover number of high-tech patents per million inhabitants and share of persons employed in the R&D sector. Electricity price in Euro per kWh and disposable income in PPS (EU-27=100) are the economic indicators. Finally, institutional and politic environment is described by the Worldwide Governance Indicators [27]: government effectiveness, regulatory quality and rule of law. Government effectiveness reflects perceptions of the quality of public services, the quality of the civil service and the degree of its independence from political pressures, the quality of policy formulation and implementation, and the credibility of the government's commitment to such policies. Regulatory Quality reflects perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development. Rule of Law reflects perceptions of the extent to which agents have confidence in and abide by the rules of society, and in particular the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence.

All of these indicators were correlated with energy consumption per capita indicators covering the period of 2001–2009. Table 1 presents the results of correlation analysis.

The correlation analysis showed that the number of high-tech patents positively impacted growth of residential energy use per capita of the United Kingdom ($r=0.91$, $p<0.05$) and the Netherlands ($r=0.67$, $p<0.05$), whereas correlation was insignificant for the remaining two states. Electricity price was negatively correlated with energy consumption in the United Kingdom ($r=-0.88$, $p<0.05$), Germany (-0.64, $p<0.05$) and the Netherlands ($r=-0.81$, $p<0.05$), whereas positive correlation was observed in Lithuania ($r=0.58$, $p<0.1$). The reciprocal link between electricity price and energy consumption confirms that

Table 1
Correlation between main drivers of residential energy use.

	Residential energy uses, ktoe			
	UK	Lithuania	Netherlands	Germany
The patents for high technologies per mill. of inhabitants, units	0.91	0.46	0.67	0.05
The share of population working in science and high technologies sector, %	−0.84	0.7	−0.64	−0.81
Electricity prices for households, Eurocent	−0.88	0.58	−0.81	−0.57
Real disposable income, EUR	0.8	0.78	0.24	0,39
Government effectiveness, index	0.94	0.49	0.84	0.56
Regulatory quality, index	−0.03	0.06	0.47	0.08
Rule of law, index	−0.68	0.64	−0.55	−0.3

price remains an effective instrument for energy consumption control. As for Lithuania, one may assume that energy consumption per capita is rather low here in terms of the West Europe states and may rise in spite of price regulation.

The share of R&D employees and energy consumption per capita was negatively related in the United Kingdom ($r = -0.84$, $p < 0.05$), Germany (-0.81, $p < 0.05$) and the Netherlands ($r = -0.64$, $p < 0.1$). Therefore, technical innovations are successfully applied in these states to reduce energy intensity. Meanwhile, Lithuania exhibited probably the manifestation of spurious correlation ($r = 0.67$, $p < 0.0.05$) due to the on-going energy consumption adjustments. The significant negative relation between the share of R&D employees and GHG emission was identified in all states except Lithuania.

There was no significant correlation found between income and energy consumption in the Netherlands and Germany. However, the positive relation holds for Lithuania and the United Kingdom.

The investigated political and institutional indicators, indeed, exhibited lower correlation with energy indicators. Government effectiveness indicator was directly correlated with both of the energy indicators in the United Kingdom and the Netherlands. The rule of law indicator was reciprocally related to energy consumption in United Kingdom. As for Lithuania, the positive link was determined between these indicators. Thus, only the rule of law indicator seems to be related to decrease in energy consumption.

The carried out analysis, however, has some limitations. Due to the limited data availability we employed correlation rather than regression analysis. Therefore only linear interactions between the selected indicators were analysed. Furthermore, simultaneous correlation does not allow lagged effects. Thus some of the observed correlations might be a result of spurious correlation.

4. Policies aiming at energy conservation in residential buildings

Different environmental policy measures provide different incentives for "environmentally responsive" consumer choices and behavioural responses. Economic instruments, such as environmentally-related taxes, are often advocated to be the most cost-effective manner to meet environmental objectives. Taxes and subsidies will have a direct effect on the relative prices and will provide incentives for polluters and resource users to reflect environmental impacts in their decisions (internalize externalities). Direct regulation, which is also often being used in EU and other developed countries can also be quite effective. Policy makers also often rely on labelling and information campaigns, which affect the knowledge based upon which choices are made.

Some recent national initiatives include the phasing out of incandescent bulbs (e.g. Australia, EU Directive), tighter minimum energy performance standards for residential buildings (e.g. Australia, Canada, Japan, EU Directive), fuel consumption labels (e.g. Canada, Korea, EU Directive), incentives to buy alternative-fuel vehicles (e.g. Canada, Norway, Sweden), congestion charges (e.g. UK, Sweden), grants for residential energy conservation projects (e.g. France, Germany), differentiated vehicle taxation (e.g. Korea, the Netherlands), rebates for investment in water efficient equipment (e.g. Australia) and organic food labelling (e.g. Canada).

Household Behaviour and Environmental Policy was initiated at the OECD Environment Directorate, in 2005, to provide guidance on the design of environmental policies targeting residential energy use

- energy taxes, energy efficiency labelling of appliances and buildings, grants to invest in energy efficient equipment, technical standards of appliances, provision of differentiated 'green' energy, etc.
- fuel taxes, congestion charges, subsidies for alternative-fuel vehicles, parking restrictions, emissions standards, quality of public transport, etc.
- pricing structure (fixed rate vs. increasing block tariff), grants for using water-efficient technologies, water efficiency labelling, etc.

In US the increases in energy consumption are mitigated by

- Mandatory codes and standards, which include Federal equipment standards, state building energy codes and equipment standards, and local building energy codes.
- Voluntary programs, such as ENERGY STAR appliances, homes, and buildings, as well as new "green" building programs;
- Policies and incentives such as federal and state tax credits; utility rebates and pricing structures; and government-backed research to develop energy-efficient technologies.

However the EU has implemented the most strict and wide policies aiming at energy efficiency improvements because of energy consumption growth during 1990–2010. The EU set the target for energy efficiency to reduce primary energy consumption by 20% compared to projections for 2020. Energy efficiency is the most cost-effective way of reducing energy consumption while maintaining an equivalent level of economic activity. Improving energy efficiency also addresses the key energy challenges of climate change, energy security and competitiveness.

Action Plan for Energy Efficiency: Realising the potential outlines a framework of policies and measures with a view to intensify the process of realising the over 20% estimated savings potential in EU annual primary energy consumption by 2020. The plan lists a range of cost-effective measures, proposing priority actions to be initiated immediately, and others to be initiated gradually over the Plan's 6-year period. Further action will subsequently be required to reach the full potential by 2020.

Commission Green Paper, 22 June 2005, "Energy Efficiency – or Doing More With Less" outlines the need to adopt specific measures to improve energy efficiency. Energy and transport play a large part in climate change since they are the leading sources of greenhouse gas emissions; this is why energy policy is particularly

Table 2
Energy saving and GHG emission reduction potential and costs in residential buildings.

Policy measures	Country/region	Energy or GHG emission reduction potential, tCO_2	GHG emission reduction costs, USD/tCO_2
Appliance standards	European Union (EU)		EU: -194 USD/tCO_2 2020
Building codes	EU United Kingdom (JK) Netherlands (NL)	EU 35–45 $MtCO_2$, 60% for new buildings JK: 2.88 $MtCO_2$, until 2010	NL: from -189 USD/tCO_2, to -5 USD/tCO_2 for final consumers, 46–109 USD./tCO_2 public consumers
Public purchases	EU	20–44 $MtCO_2$	<21 USD/tCO_2
Energy efficiency agreements and quota system	(JK)	JK: 2.16 $MtCO_2$/year	139 USD/tCO_2
Labelling and certification programmes (obligatory)	Australia (AUS)	5 $MtCO_2$ savings during 1992–2000 and 81 $MtCO_2$ during 2000–2015	AUS: -30 USD/tCO_2
Demand side management programmes in Energy supply companies	Denmark (DK) EU	DK: 0.8 $MtCO_2$	DK: -209.3 USD/tCO_2 EU: -255 USD/tCO_2
Energy service obligations	EU	40–55 $MtCO_2$ until 2010	<22 USD/tCO_2
White certificate trading	Italy (I) France (Fr)	I: 1.3 $MtCO_2$ until 2006; 3.64 $MtCO_2$ until 2009	Fr: 0.013 USD/tCO_2
Flexible Kyoto mechanisms	Estonia Latvia	Estonia: 3.8–4.6 kt CO_2 Latvia: 830–1430 tCO_2	Estonia: 41–57 USD/tCO_2 Latvia – 10 USD/tCO_2
Taxes	Netherlands (NL)	0.5–0.7 $MtCO_2$ in 2000	–
Allowances	France (Fr)	1 $MtCO_2$ in 2002	–
Public service obligation taxes	Netherlands (NL)	2.5 $MtCO_2$	–
Subsidies	JK	6.48 $MtCO_2$/year and total 100.8 $MtCO_2$	29 USD/tCO_2
Voluntary agreements	EU Sweden (SE)	EU: 50 kt CO_2, 100 GWh/year	SE: 0.0166 USD/kWh
Public leadership programmes	Germany (DE) EU	DE: 25% of CO_2 reduction in public sector during 15 years	EU: 13.5 bill. USD savings until 2020.
Information dissemination	JK	10.4 $ktCO_2$/year	8 USD/tCO_2
Detailed bills	JK	3%	–

important in the European Union's sustainable development strategy. The EU is increasingly dependent on energy imported from Non-EU Member Countries, creating economic, social, political and other risks for the Union. The EU therefore wishes to reduce its dependence and improve its security of supply by promoting other energy sources and cutting demand for energy. Consequently, it is putting the accent, above all, on improving energy efficiency and promoting renewable energy sources.

Currently, only a few comprehensive comparative assessments of policy instruments for promoting energy efficiency in the buildings sector are available. However it is very important to assess and compare the most important policy instruments for achieving energy efficiency improvements and GHG emission reductions in buildings according to their emission reduction effectiveness, cost-effectiveness. Today, more than 30 policy instruments are in use, including for example appliance standards, public leadership programs, pricing schemes and many more.

The policy instruments are classified into the following categories:

- regulatory and control mechanisms: laws and implementation regulations that require certain devices, practices or system designs to improve energy efficiency;
- economic/market-based instruments are usually based on market mechanisms and contain elements of voluntary action or participation;
- fiscal instruments and incentives usually correct energy prices either by a Pigouvian tax aimed at reducing energy consumption or by financial support if first-cost related barriers are to be addressed;
- support, information and voluntary action. These instruments aim at persuading consumers to change their behaviour by providing information and examples of successful implementation.

Based on analysis [8,10–16,28] Table 2 was developed summarizing energy saving and GHG emission reduction costs and potentials in residential buildings.

The highest GHG emission reductions in the sample were achieved by appliance standards, building codes, DSM programs, tax exemptions and labelling. Among the most cost-effective instruments were appliance standards, energy efficiency obligations, Demand Side Management SM programs, public benefit charges and labelling. Most of these are regulatory and control instruments. Appliance standards are especially cost-effective with net projected societal benefits of $-65\$/tCO_2$ in 2020 in the United States and $-194\$/tCO_2$ in 2020 in the European Union. An important success factor for these is the continuous evaluation and regular updating of the thresholds to reflect changing market conditions and ambitious targets.

5. Energy saving policies in Lithuanian residential buildings

The residential and public buildings can be considered a building sector. The main policy document to promote energy efficiency in Lithuania is National Energy Efficiency Programme for 2006–2010 approved by the Government of the Republic of Lithuania in 2007. It sets the following targets: renovation of buildings and updating their energy facilities increasing energy efficiency of energy production and use in all sectors, with special attention to district heating, industrial processes, household and transport sector; usage of renewable, local and secondary energy resources. Modernization of multi-apartment buildings is planned in all energy efficiency related programmes. It is expected to modernize at least 70% of all multi-apartment buildings (24,000 units). It is supposed to reduce relative consumption of thermal energy per unit of the used dwelling area by up to 30%, compared with the year 2004. Savings targets for 2010 are 150 GWh if early actions are excluded, and for 2016–1700 GWh. Programme started in 2005 and its completion date is the year 2020. During the period 2007–2008 the investments in modernization of multi-flat buildings amounted to 58.8 mill. LTL and 480 buildings were

renovated. The total energy savings make 13 GWh. From EU Structural funds (2007–2013) 163.5 mill. LTL were foreseen for multi-flat buildings renovation to increase energy use efficiency. Achieved energy savings due to renovation of 500 buildings until 2010 makes about 15.3 GWh.

Modernization of public buildings is implemented via different programs in Lithuania, which are listed below [9]

1. 2004–2006 EU Structural Funds for energy use efficiency improvement in public buildings. The total energy savings make about 5.5 GWh.
2. 2007–2013 EU Structural Funds (for reduction of energy consumption in public buildings), savings targets for 2010 – 30 GWh, and for 2016 – 100 GWh, the programme started in 2007 and its completion year is 2015. Achieved energy savings make 46.7 GWh in 2010.
3. Programme of renovation and reconstruction of science and studies institutions for 2007–2009; savings targets for 2010 – 17 GWh, 2016 m. – 17 GWh, programme started in 2007 and finished in 2009. Achieved energy savings in 2010 make about 17 GWh;
4. Programme of renovation of university student halls; savings targets for 2010 – 6 GWh, and for 2016 – 6 GWh; programme started in 2006 and ended in 2009. Achieved energy savings in 2010 make 25 GWh;
5. Programme of renovation and provision with teaching aids of general education schools and vocational education and training establishments for 2006–2008; Savings targets for 2010 – 7 GWh, and for 2016 – 7 GWh, programme started in 2006 and finished in 2008. Achieved energy savings in 2010 make 10 GWh;
6. Programme of renovation and upgrading of libraries for 2003–2013; savings targets for 2010 – 3 GWh, and for 2016 – 5 GWh, programme started in 2003 and its completion year is 2013. Achieved energy savings in 2010 make 2 GWh.
7. Programme of renovation of imprisonment institutions and humanization of imprisonment conditions for 2004–2009, savings targets for 2010 – 5 GWh, and for 2016 – 5 GWh. Programme started in 2004 and finished in 2009. There are no information on achieved energy savings;
8. Programme of modernization of cultural centres for 2007–2020; savings targets for 2010 – 2 GWh, and for 2016 – 8 GWh, Programme started in 2007 and its completion year is 2020. Just two projects were initiated however they were not completed. There is no information on achieved energy savings.
9. Programme of modernization of museums for 2007–2015; savings targets for 2010 – 4 GWh, and for 2016 – 14 GWh. Programme started in 2007 and its completion year is 2015. Just one object was modernized. Achieved energy savings are negligible.
10. Modernization of public buildings from Special programme “Implementation of energy saving projects”. During 2004–2008 it was foreseen to achieve 6 GWh of energy savings in 2008. 22 projects were financed. There are no information on achieved energy savings.
11. Programmes of construction, reconstruction, repairs and material provision of municipal buildings used for educational, cultural, health care, social and other purposes; savings targets for 2010 – 5 GWh, and for 2016 – 5 GWh. 2003–2007 programmes are implemented and programme for 2008 is under implementation. The programme started in 2003 while its completion time has not yet been set. There is no information on achieved energy savings.
12. Modernization of public buildings from Lithuanian Environmental Investment Fund. Achieved energy savings in 2010 make 2 GWh.

Energy saving target (726 GWh in 2010 excluding early actions) set in Energy Efficiency Action plan for 2010–2016 was not implemented in 2010 (achieved savings make just 50% of the target set for 2010). Just in Service sector (which accounts just for 5% of total energy saving potential in 2010) the achieved energy savings in 2010 are higher by 205% comparing with target. In the household sector (which accounts for 37% of total energy saving potential in 2010) because of the fall of the Programme of modernization of multi-flat buildings (renovated 980 buildings instead of 24,000) the achieved energy savings 28 GWh makes just 18.6% of targets set by action plan.

6. Energy saving potential and costs in Lithuanian residential buildings

About 45% of total final energy consumption is used in residential buildings. Whereas more than 60% of the Lithuanian

Table 3
Energy saving potential and costs in Lithuanian residential buildings.

Energy saving measures	Costs for households		Energy saving potential		GHG emission reduction potential			Costs
	Lt/m^2	Lt/kWh	In household, kWh/m^2 per year	Total TWh/year	Energy carrier	GHG Mt CO_2 eq/year	Mill. Lt	Lt/t CO_2 eq/year
Insulation of multi-flat buildings	5 LTL/m^2/	0.1 Lt/kWh	50 kWh/m^2 per year	3 TWh	Heat	0.684	300	439
Passive buildings	50 LTL/m^2/	0.5 Lt/kWh	100 kWh/m^2 per year	0.9 TWh	Heat	0.205	450	2195
Installation of individual control systems in multi-flat-buildings	0.1 LTL/m^2/	0.33 LTL/kWh	0.30 kWh/m^2 per year	0.02 TWh	Heat	0.005	7	350
Solar collectors	–	0.50 LTL/kWh	50% for energy used to heat water or 1000 kWh/year	1.425 TWh	Heat	0.283	713	2519
Heat pumps	–	0.36 LTL/kWh	70 kWh/m^{2}metus	4.2 TWh	Heat	0.958	1512	1578
Replacement of electric equipment by new one	–	0.05 LTL/kWh	50% of total electricity consumed by appliances or 150 kWh/year	0.2138 TWh	Electricity	0.107	11	102,8
Replacement of old bulbs by fluorescent bulbs	–	0.03 LTL/kWh	50% of electricity consumed for lighting or 800 kWh/year	1.14 TWh	Electricity	0.570	34	67
Smart houses	500 LTL/m^2/	25 LTL/kWh	60% electricity consumed by household or 120 kWh/m^2	7.2 TWh	Electricity and heat	2.620	3600	1374
Total				18 TWh		5.4	6627	1227

Table 4
Energy saving and GHG emission reduction potential and costs in residential and other sectors.

Energy saving measures	Energy savings		GHG emission reduction	
	Energy saving potential, TWh/year	Energy saving costs, LTL/kWh	GHG emission reduction potential, Mt CO_2 eq/year	GHG emission reduction costs LTL/t CO_2 eq
Energy saving in residential sector achieved by product innovations and efficiency improvements	10.9	0.277	2.8	2590
Energy saving in residential sector achieved by curtailment behaviour changes	3.4	–	1.1	–
Energy savings in energy supply sector	9.2	0.120	1.9	2–170
GHG emission reduction in agriculture	–	–	0.1	1125
GHG emission reduction in waste sector	–	–	0.1	1370
GHG emission reduction in industrial processes	–	–	2.4	315–560
Total	–		8.5	

population resides in multi-apartment buildings constructed during 1961–1990, which are not complied with the effective requirements, this sector has great energy saving potential.

The COWI study addresses the GHG emission reduction options and costs across all sectors of the Lithuanian economy. The purpose of this study is to give the approximation of costs in Lithuanian economy in the case of the carbon emission target tightening. Given the unavailability of suitable models of energy use in Lithuanian residential building stock as well as a broad scope and resource limitations, this study has employed a quite simplistic approach evaluating costs to reduce CO_2 emission in buildings. The three technologies were chosen for assessment of energy saving costs and potentials to replace existing gas boilers by pellet boilers; to install heat pumps instead of existing gas boilers; and to install solar collectors in order to diminish electricity consumption in domestic hot water heaters. Evaluation of the costs in the COWI study indicated the energy saving potential of the 3 technologies under investigation could reach 87.5 kt CO_2 emission reduction annually. That would require 371 million LTL in total or 353 LTL of investments per one ton of CO_2 emission mitigation annually [6,7].

Fraunhofer ISI study [8] evaluated the economic potential of final energy savings in Lithuania as 759 ktoe in 2020, 38% of this energy could be saved in residential and public buildings. The major part of savings, 221 ktoe could be achieved as fuel savings in buildings, mostly for space heating [8]. The rest 68 ktoe of final energy goes to electricity savings, mainly in public buildings. Given the carbon intensity factor of electricity from the grid is 0.707 tCO_2/MWh_{el}, then 68 ktoe of electricity savings correspond to 559 kt CO_2 reduction. Assuming that the carbon intensity factor of district heating is 0.223 tCO_2/MWh_{th}, the savings in heating will yield 573 kt CO_2 [6].

Energy saving potential in Lithuania achieved by innovations in residential sector is presented in Table 2. The potential was evaluated based on results of studies conducted in Lithuania [6–8,29,30]. GHG emission reduction potential was also assessed in Table 3 by applying national emission factors [31]. The carbon intensity factor of electricity from the grid is 0.707 tCO_2/MWh_{el}, then carbon intensity factor of district heating is 0.223 tCO_2/MWh. These factors were obtained by applying Lithuanian national GHG emission factors [31].

As one sees from information presented in Table 3 the total GHG emission reduction potential in residential buildings makes 5.4 Mt and the average cost is 1227 Lt/tCO_2 eq. It is necessary to stress that this is technical potential and these measures will never be implemented all together. Based on information provided in Table 3, Table 4 was developed seeking to assess and compare energy saving costs and potential in residential sector in Lithuania including measures related to behavioural changes [32,33]. In Table 4 energy saving and GHG emission reduction costs and potential achieved because of implementation of policies and measures in various sectors of economy and in residential sector are presented.

As one sees from information provided in Table 4 because of implementation of policies and measures in the main GHG emission sectors it is possible in 2008–2012 to reduce GHG emission by 4.2 Mt per year in Lithuania without energy saving in residential sector. In energy sector it is possible to reduce GHG emissions by 2 Mt/year besides that in this sector GHG emission reduction costs are the lowest one and makes about 2–170 Lt/tCO_2, then in other sectors these costs are significantly higher.

By comparing energy saving potential in residential buildings obtained for behavioural changes in energy consumption one can notice that energy saving potential because of product innovations is more than twice higher however to exploit the huge investments that are necessary. In energy supply sector GHG emission reduction potential is lower if new nuclear power plant is not being considered as GHG emission reduction measure. By comparing energy saving costs in residential sector obtained by product innovations and in energy supply sector one can notice that energy saving and GHG emission reduction costs are lower in energy supply sector. However energy saving potential in residential buildings obtained for behavioural changes can be achieved at no costs and with net social benefit because it allows energy costs savings without any investments. Another important fact is that GHG intensity of energy saving potential in residential buildings because of behavioural changes causes higher GHG emission reduction rate comparing with energy saving potential achieved by product innovations as these energy savings are mainly attributed to the savings of motor fuels having high carbon intensity. At the same time energy savings in residential buildings obtained by product innovations are mainly related with district heat or electricity savings having lower carbon intensity.

7. Conclusions

The analysis of residential energy use per capita indicated that residential energy use per capita in Lithuania is significantly lower than in old EU members states such as United Kingdom, the Netherlands, or Germany because of lower income per capita and lower living standards.

The analysis of the main drivers of residential energy use in Lithuania, the Netherlands, United Kingdom and Germany indicated that economic and technological factors are the main driving forces of final energy consumption however the impact of different factors varies between countries.

The performed comparative study revealed that in old EU member states the prices and share of R&D employers have impact on energy consumption reduction; however in Lithuania because of low energy

consumption per capita and low living standards the impact is opposite. Institutional indicators exhibited lower correlation with energy consumption indicators; however the rule of law indicator seems to be related to decrease in energy consumption in all countries.

Lithuania like other EU member states has ambitious energy efficiency improvement policies targeting residential buildings. The Programme of modernization of multi-flat buildings was an excellent instrument to cope with energy intensity decrease in Lithuanian residential buildings; however this programme has failed and the economic crisis had the most painful impact on shrinking of Lithuanian construction sector.

The economic incentives for households to renovate their apartments are necessary in Lithuania as state supports just 25% of total investments in modernization of multi-flat buildings. The support intensity needs to be increased up to 75% as in the case of successful programs of public buildings renovation conducted during 2004–2010 in Lithuania and other new EU member states.

The comparison of GHG reduction potential in residential buildings obtained for behavioural changes with GHG emission reduction potential achieved by product innovations in Lithuania showed that GHG reduction potential attained by product innovations is higher, however, seeking to exploit it huge investments are necessary. The GHG emission reduction costs make more than 2000 Lt/tCO_2. Only in the field of old buildings renovation and switching from old bulbs to light diodes GHG emission reduction costs are low enough however GHG emission reduction potential in this case is comparatively low.

Though energy savings in Lithuanian residential sector achieved by product innovations allow to save almost 3 times more energy comparing with energy saving obtained for behavioural changes; however avoided GHG emissions obtained for behavioural changes are almost twice lower comparing with product innovations as these energy savings are mainly attributed to the savings of motor fuels having high carbon intensity. At the same time energy savings in residential buildings attained by product innovations are mainly related with district heat or electricity savings having lower carbon intensity and consequently lower GHG emission reduction potential.

The analysis of energy saving and GHG emission reduction potential and costs in residential buildings provided by different studies showed provided that the most cost-effective instruments were appliance standards, energy efficiency obligations, Demand Side Management programs, public benefit charges and labelling. Appliance standards are especially cost-effective with net projected societal benefits of -65 USD/tCO_2 in 2020 in the United States and -194 USD/tCO_2 in 2020 in the European Union.

Lithuania needs to develop energy efficiency improvement policy and to apply new instruments which were successfully implemented in other countries to promote energy savings in residential buildings. The highest GHG emission reductions potential in Lithuanian residential buildings can be achieved by implementing appliance standards, building codes, DSM programs, tax exemptions and labelling.

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